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Evidence of a trait-specific response to burning in springtails (Hexapoda: Collembola) in the boreal forests of European Russia

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ABSTRACT

The reaction of soil fauna to forest fires is highly variable in space across large ecoregions, the reasons for which are still not completely documented. We tested regional differences in the response of springtail (Hexapoda: Collembola) taxonomic richness, total abundance and collembolan abundance, which share combinations of the two traits (reproduction mode and vertical distribution), in a pilot study within boreal forests of European Russia. We selected four stands burned five years ago and four respective controls in each of the three boreal forest subregions: northern, middle and southern taiga. Plots were located along a 1500 km-long north-south transect covering most of the existing climatic and edaphic gradient within this ecoregion. The General Linear Model (GLM) results showed that fire had a significant effect on the abundance of collembolans that shared certain trait combinations (sexually reproducing epiedaphic species), while the total collembolan abundance depended on the forest subregion, but not burning. The abundance of sexually reproducing epiedaphic springtails decreased in burned plots by 40%, on average, in comparison with the respective controls. This reduction was positively correlated with the degree of fire severity and negatively correlated with litter thickness and soil water holding capacity. We conclude that fires induce a consistent shift in the composition of the springtail functional trait community, which is driven more by the forest stand level of litter thickness and moisture than by subregional forest differences. Our study revealed the potential of the functional trait composition to be a sensitive and informative tool for tracing the effects of fire in boreal forests, which is relatively independent from regional differences.

1. Introduction

Forest fires act as an important environmental factor that shape the dynamics and composition of flora and fauna in boreal forest ecosystems (Goldammer and Furyaev, 2013; Niklasson and Granström, 2000; Granström, 2001; Ryan, 2002). Boreal forests occupy the largest share of land in Russia, with a total area of approximately 600 million ha (Conard and Ivanova, 1997). The fire regimes in taiga are highly variable in space and time and depend on a diversity of factors such as climate, vegetation, topography and human pressures (Carcaillet et al., 2001; Kasischke and Turetsky, 2006). The resulting fire frequency may vary on average from 14 to 23 years in Central Siberia (Furyaev and Kireev, 1979) to 58–71 years in the European part of Russia (Goldammer and Furyaev, 2013; Vakurov, 1975). The same is true for fire intensity, severity and its type (crown or ground fire) (Shorohova et al., 2009). These differences will undoubtedly imply spatial variability in the pyrogenic recovery patterns of all groups of organisms inhabiting coniferous forests. However, such a spatially explicit analysis has been performed for only a few taxa so far (Butenko et al., 2017; Korobushkin et al., 2017).

Ground fires prevail in European boreal forests (Gromtsev, 2002). They can severely damage vegetation, litter and the top humus horizon (De Bano et al., 1998; Certini, 2005). This consequently affects soil organisms due to direct heat and toxic smoke effects, as well as the destruction of microhabitats. As a result, belowground ecosystems in boreal forests are subject to the strong, and at the same time, complex effects of fires. This is reflected in the short-term reduction in the abundance and species richness of soil taxa and their different rates of recovery after burning (Bezkorovainaya et al., 2007; Malmström et al., 2008; Malmström et al., 2009; Wikars and Schimmel, 2001). Post-fire recovery of soil fauna is not only group-specific but also depends on the pre-fire parameters of their habitats (e.g., hydrothermal conditions, soil type, microhabitat diversity, etc.) as well as a long list of fire properties (e.g., heterogeneity and severity of fire) (Scott et al., 2014; Webb,

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